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CONTRIBUTIONS TO A REVISION OF THE EARTHWORM FAMILY LUMBRICIDAE
V. *EISENIA ZEBRA* MICHAELSEN, 1902[1]

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Twenty species of lumbricid earthworms, brought by man from Europe since 1500 A. D. (Gates, 1966 and 1967), have been found to be variously domiciled in North America. Another species, that may eventually become widely distributed throughout the continent, is now added to the list. At least one more, perhaps others, will be added later.

American material and data were supplied by Mr. Salvatore Billeci. For comparison, an identified series of the same species from Wales was provided by Dr. K. Sylvia Richards.

Eisenia Malm, 1877 (emend. Gates, 1968)
Eisenia zebra Michaelsen, 1902

Eisenia veneta var. *zebra* Michaelsen, 1902. Mitt. Naturhist. Mus. Hamburg, 19, p. 39 (Type locality, Chosta, Kreis Sotschi, Transcaucasia. Type, supposedly in the St. Petersburg Mus.)

Helodrilus (*Eisenia*) *venetus* var. *zebra,* Michaelsen, 1910. Ann. Mus. Zool. Acad. Sci. St. Petersburg, 15, p. 3.

Dendrobaena veneta var. *zebra,* Pop, 1943. Ann. Hist. Nat. Mus. Hungarici, (Zool.), 36, p. 22. Brinkhurst, 1962, Proc. Zool. Soc. London, 138, p. 325. Gerard, 1964, Linnean Soc. London, Synopses British Fauna, No. 6, p. 39, etc.

Material examined: San Francisco, California, 1–3–20(+), received on several occasions from S. Billeci. Identified specimens, from Britain, 1–1–32, provided by K. Sylvia Richards.

External characteristics: Size, 51–96 by 5 (an aclitellate) to 8 mm. Segments, 83–153 (Table), 113–153 (unamputated specimens). The majority of the unamputated worms have segment numbers in the range of 127–147. The average for 44 unamputated specimens (Table, Nos. 10–59 but

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Typhlosole termination and segment number in *Eisenia zebra*

Serial number	Typhlosole ends in segment	Atyphlosolate segments	Soma segments	Serial number	Typhlosole ends in segments	Atyphlosolate segments	Soma segments
1	78	5	83	31	121	16	137
2	79	4	83	32	121	19	140
3	83	4	87	33	122	14	136
4	88	7	95	34	122	15	137
5	93	10	103	35	122	17	139
6	94	6	100	36	123	13	136
7	94	8	102	37	123	14	137
8	98	8	106	38	123	16	139
9	98	11	109	39	123	17	140
10	101	12	113	40	125	15	140
11	106	10	116	41	125	16	141
12	109	8	117	42	126	8	111
13	109	11	120	43	126	16	142
14	109	12	121	44	128	14	142
15	110	16	126	45	128	15	143
16	110	18	128	46	128	15	143
17	111	15	126	47	129	15	144
18	112	16	128	48	130	4	134
19	112	18	130	49	130	8	138
20	114	15	129	50	130	14	144
21	117	15	132	51	130	15	145
22	117	19	136	52	130	16	146
23	118	16	134	53	130	16	146
24	118	17	135	54	131	16	147
25	119	8	127	55	131	17	148
26	119	15	134	56	132	16	148
27	119	18	137	57	135	8	143
28	120	8	128	58	137	10	147
29	120	15	135	59	137	16	153
30	120	18	138				

NOTES

Worms numbers 2, 9, 14, 17 were posterior amputees having each an obviously regenerated periproct.

The typhlosole of No. 12 was rudimentary in the 108th–109th segments, having been reduced after posterior amputation.

Those of Nos. 1–9 not already mentioned probably were old posterior amputees. Those numbered 25, 28, 42, 49, 57 are believed to be posterior amputees.

Coelomic cavities of the last few segments in Nos. 40 and 41 were filled with brown bodies of various sizes and shapes.

excluding 12, 28, 42, 48, 49, 57) is 136.5. The mean number of segments for 47 specimens is 136.4681, with a standard deviation of 8.5539 and a standard deviation of the mean of 1.2477. A majority of the worms have segments in a range of 134–148, which is about the size of the range for the majority of *E. hortensis* (Gates, 1968b). Color, dark red to slate, in

transverse bands, leaving a fairly wide uncolored band centered at each intersegmental furrow, sparse in some portion of the dorsum in ix–x. Soma, posteriorly almost transversely rectangular in cross section with *b* and *d* setae at the four corners. Prostomium epilobous, tongue open (all). When the pre-oral lobe is drawn more or less completely inside the buccal cavity, the lobe is demarcated from the tongue by a transverse furrow. Such a condition is called "combined pro- and epilobous". Several worms were almost tanylobous. The periproct often is large, with an anterior portion showing evidence of differentiation of another metamere, such as presence of a dorsal pore (which may not be functional) or presence of setae more anteriorly. If both conditions are recognizable the area was counted as two segments even though not yet demarcated from each other by an intersegmental furrow. Secondary annulation, lacking.

Setae, present from ii, widely paired, *CD* ca. = or very slightly < *AB*, *BC* slightly < or ca. = *AA* < *DD* < ½C. Nephropores, inconspicuous, actual pores never seen, locations occasionally recognized, probably at *B* in xiv, xv usually, at or above *D* in first few segments, elsewhere varying irregularly and with asymmetry between a ventral level just above *B* and a dorsal level above *D*. First dorsal pore, at 4/5 (1 specimen), 5/6 (35), pores at 9/10, 10/11 of clitellate individuals occluded.

Clitellum, saddle-shaped, reaching down below *C*, dorsal pores occluded, intersegmental furrows not obliterated, (xxvi)–xxxiii (4), xxvi–xxxiii (29), xxvi/eq-xxxiii (1), xxvii–xxxiii (7), (xxvii)–xxxiii (1), xxviii–xxxiv (1). Tubercula pubertatis, longitudinally placed, often bounded laterally by a distinct furrow, median borders often uncertain and seemingly just including *b* setae, anterior and posterior borders usually uncertain, xxix–xxxi (10), xxix/eq-xxxii/eq (10), xxix/eq-xxxii (4), xxx–xxxi (14), xxx–xxxii/eq (1), xxx–xxxii (4). Sometimes a nearly circular portion in each of xxx and xxxi seems more prominent.

Genital tumescences, slight, boundaries very indistinct, including some or all of the setae in ix or xii, *a,b* separately in xxviii–xxxi (2), xxviii–xxxii (3), xxix–xxx (3), xxix–xxxi (3), xxix–xxxii (17).

Internal anatomy: Septa, 5/6–12/13 slightly strengthened, 13/14–15/16 muscular and increasingly thickened posteriorly.

Special longitudinal muscle band at mD, present from 5/6. Pigment, red, in circular muscle layer. Peritoneum blistered away from musculature in dorsum of ix–xi. Broad transverse stripes of pigment sometimes are associated with the dorsal peritoneum anteriorly.

Calciferous sacs and lamellae, lacking in x. Esophagus widest in xi–xii where the lumen is narrow. Usually no marked external constriction at insertion of 11/12. Lamellae are largest in xi in which segment the gut always is whiter or redder than anteriorly or posteriorly. Esophageal valve, in xiv (35). Intestinal origin, in xv (35). That portion of the intestine belonging in xv occasionally has been drawn back into gut lumen of xvi. Gizzard, mostly in xvii, but fenestration dorsally of 17/18 and 18/19 contributes to an appearance of greater posterior extent. Typhlosole, present from region of xxii, at first with widened and flat ventral

face. A cross section at first has an inverted T-shape but subsequently is obviously though only slightly bifid. The typhlosole ends as shown in the table but, when there was no posterior amputation, in region of the 101st to 137th segments, usually in the 110th–130th. Up to 18 intestinal segments were atyphlosolate.

Dorsal blood vessel, single, recognizable forward only to 5/6. However, in one worm, a small section of the trunk among the pharyngeal glands was blood-filled and traceable to a bifurcation under the brain. Ventral trunk, complete, bifurcating over subpharyngeal ganglion. Subneural trunk, complete, bifurcating at anterior end of the nerve cord, adherent to cord but when distended coming easily away. Extra-esophageal trunks, median to hearts, turning up to dorsal trunk in xii (35). Hearts, in vii–xi (35), none seen in vi.

Nephridia, vesiculate. Bladders, elongately sausage-shaped, transversely placed in *BD* or reaching beyond *D*, joined at lateral end by looped tubule, narrowing as they pass downward and into parietes close to *B* but without a distinct duct.

Holandric. Testes and male funnels free in coelomic cavities. Male funnels, polyplicate, sometimes complexly so and then rosette-like. Male gonoducts, without epididymis (35), passing straight laterally to parietes, disappearing from sight in an anterior portion of the atrial glands in xiv. Seminal vesicles, 4 pairs, smallest in x, the last pair largest and at height of maturity extending in posterior pockets of 12/13 back to level of 14/15.

Ovaries, each with a terminal egg string that may contain 4–7 ova (35). Ovisacs, present in xiv (35). Spermathecae, in ix and x (35), each with a short and slender but definitely coelomic duct. Ampulla, spheroidal to ovoidal, occasionally more or less reniform to almost bilobed.

TP glands, acinous, more or less conspicuously protuberant into the coelomic cavities, just lateral to *B*. Atrial glands, acinous, usually entirely within the body wall which is markedly bulged into the coelomic cavities of xiv–xvi in the median portion of *BC*. An equatorial cleft is obvious in xv. Setal follicles of ix (2), xii (24) are enlarged, conspicuously protuberant in the coelom, each surrounded by a rosette of acinous supraparietal glands. Setae of those follicles are of the usual genital sort. The body wall ventrally in *BB* of xvi–xxiii is blistered away from the musculature and the space between peritoneum and muscles is filled with a delicate coagulum. GS glands were not certainly distinguished among the blisters.

Reproduction: Spermatozoal iridescence on male funnels of clitellate worms showed that maturation of sperm had been completed. Iridescence in the spermathecal ampullae proved the worm had copulated. In absence of any contra-indication, reproduction accordingly can be assumed to be amphimictic.

Some of the spermatophores obtained were found to contain sperm.

Distribution: Outside of Russia, *E. zebra* had been found in Turkey, Wales, England, Ireland, but records for extra-Russian areas are few.

Cocoons: Color, a light lemon-yellow, perhaps becoming brown later. Shape, tapering slightly at each pole to a protuberance. One terminal

protuberance usually is markedly thicker than the other but length and shape of each free end vary considerably. Micrometer measurements supplied by Mr. Billeci are as follows: Diameter, at thickest equatorial portion, 0.1415, 0.143, 0.144, 0.145 (twice), 0.146 inches. Average of the six measurements, 0.144 inch. Length, exclusive of the polar appendages, 0.125, 0.126, 0.138, 0.154, 0.155 (twice), 0.158 (twice), 0.159, 0.165, 0.186, 0.201 inches. Average of twelve cocoons, 0.1568 inch.

Spermatophores: One was noted on each of four worms, two were seen on each of two worms. Always discoidal and transparent, shape varied from subcircular to elliptical. Each had a small, opaque central thickening that contained sperm. Locations: across 27/28, in *AB* or centering at *B*, or extending across all of xxviii–xxix and centering at *A*.

Autotomy: No. 1 had half completed breaks in body wall, on left side only, at 102/103 and 93/94. No. 2 had a half completed break on left side at 80/81. No. 3 had completed a break on the right side at 89/90. No. 4 had a completed break in ventral body wall only at 88/89, but at 103/104 the break had been completed—the parts held together only by cuticle.

Regeneration: Absence of head and tail regenerates, except for four periprocts, in a total of more than 60 specimens seems unusual especially in comparison with its relative *Eisenia foetida* (Savigny, 1826).

Abnormality: Three spermathecae were present in x (1).

Parasites: Long nematodes were present in the ventral blood vessel (2 hosts). Seminal vesicles of ix,x (1 worm) were filled with small cysts and similar cysts were present in coelomic cavities of x–xi.

Remarks: From an anterior portion dorsally of a worm that was about to be put on hook there came out a creamy yellow fluid. The liquid, which may have been from distended spermathecae, had a strong odor, according to Mr. Billeci and two of his party, like that of decaying bananas.

SYSTEMATICS

Eisenia veneta (Rosa, 1886) has been at one time or another in five lumbricid genera, *Allolobophora*, *Bimastos*, *Dendrobaena*, *Eisenia*, *Helodrilus*. At present some European specialists place the species in *Dendrobaena* while others refer it to *Eisenia*.

Eisenia, recently redefined (Gates, 1968a) in accordance with conservative somatic anatomy, lacks calciferous sacs. The calciferous gland opens directly, *i.e.*, without intervention of sacs, into the gut lumen in xi. The calciferous gland of specimens identified by Michaelsen as the typical form of "*Helodrilus venetus*" was studied by Smith (1924, p. 27). He stated that the anterior end of the gland was in x as Omodeo (1952, p. 190) also thought. Actually a portion of the gut belonging in xi had been herniated into x as Omodeo later (1954, p. 128) discovered.

Insofar as the calciferous gland and "var. *typica*" are concerned Rosa's *veneta* probably can go in *Eisenia*. However, confirmation is required from other somatic anatomy.

Sixteen varieties of *E. veneta* were given Latin names by European

zoologists. Some still are in use. One, var. *hortensis* Michaelsen, 1890, now more adequately characterized (Gates, 1968b) is recognized as a species. Another, var. *hibernica* Friend, 1893, subsequently will be shown to be distinct. Other taxa are distinguishable at present from each other, if at all, only by characters of dubious systematic value (*cf.* Omodeo, 1952, p. 8 and/or Gerard, 1964, p. 38–39). The definition of "f. *typica*" (Gerard, 1964, p. 38) almost covers the entire range of variation in all varieties. By 1893 Rosa himself already had referred to his "*veneta*" individuals with a clitellum extending from xxiv, xxv, xxvi, or xxvii through xxxiii or xxxiv.

Information as to existence of types of Rosa's *veneta*, as well as material of various varieties (including f. or var. "*typica*"), has been unobtainable. Michaelsen's variety, so far as can be discovered from the literature, has been recognized on several occasions without difficulty. Populations from which the present samples were obtained seemingly are amphimictic. The taxon described above accordingly must be regarded as a species. If specific distinctness from Rosa's f. "*typica*" is demonstrable, Michaelsen's name probably can be retained. At least it has priority over remaining unplaced varietal names.

Further discussion of most relationships should be postponed until other varieties of *veneta* have been adequately characterized.

In America, *E. zebra* is easily distinguished from its congeners: From *E. foetida*, by its thicker soma, greater number of segments, wider pairing of setae, more posterior invariant section of the clitellum, more posterior anterior margin of tubercula pubertatis, calciferous lamellae largest in xi (rather than xii), a more posterior typhlosole termination (usually in region of 110th–130th rather than 80th–98th segments), a more posterior junction of extra-esophageal and dorsal trunks (in xii instead of ix–x), absence of epididymis in male gonoducts, greater development of atrial glands, presence of TP glands and of acinous, supraparietal GS glands. Many of such characters were derogated or ignored by previous specialists.

From *E. hortensis* (*cf.* Gates, 1968b), by the larger soma, greater number of segments, more obvious restriction of pigment to transverse intrasegmental bands, invariant portion of the clitellum comprising xxviii–xxxiii (rather than xxviii–xxxii), typhlosole termination usually in 110th–130th (rather than 72'd–92'd) segments, etc.

Enterion roseum Savigny, 1826, (common in America), according to American and some European zoologists is in *Eisenia*. Other Europeans refer it to *Allolobophora*. The species belongs in neither genus but determination of its proper position awaits further lumbricid revisions. Savigny's species is readily distinguished from all *Eisenia* spp. by presence of calciferous sacs in x and by the U-shape of nephridial vesicles.

ADDENDUM

European lumbricids now domiciled in North America are: *Allolobophora chlorotica* (Savigny, 1826), *A. limicola* Michaelsen, 1890, *A. longa*

Ude, 1895, *A. muldali* Omodeo, 1956, *A. trapezoides* (Duges, 1828), *A. tuberculata* Eisen, 1874, *A. turgida* Eisen, 1874, *Dendrobaena mammalis* (Savigny, 1826), *D. octaedra* (Savigny, 1826), *D. rubida* (Savigny, 1826), *Eisenia foetida* (Savigny, 1826), *E. hortensis* Michaelsen, 1890, *E. rosea* (Savigny, 1826), *E. zebra* Michaelsen, 1902, *Eiseniella tetraedra* (Savigny, 1826), *Lumbricus castaneus* (Savigny, 1826), *L. festivus* (Savigny, 1826), *L. rubellus* Hoffmeister, 1843, *L. terrestris*, Linnaeus, 1758, *Octolasion cyaneum* (Savigny, 1826), *O. tyrtaeum* (Savigny, 1826).

E. zebra, like three other species, has not been intercepted from earth with plant shipments.

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